WHITE PAPER

Bringing Intelligent Headlamps to Light via Simulation

Intelligent headlamps are in the spotlight today for a number of reasons. First, they increase the safety of nighttime driving for every driver, by sensing the surrounding physical environment and creating just the right amount of illumination. Second, they support the global movement toward automated driving (AD) by adjusting the car's lighting conditions automatically, with no human intervention — allowing all optical AD sensors to perform more effectively at night. But, given the huge range of lighting levels, terrains and roadway conditions vehicles will encounter in the real world, how can intelligent headlamps be verified for safety? The time and costs involved in road testing make this strategy prohibitive, but engineering simulation provides a solution. By leveraging the power of Ansys SPEOS, Ansys SCADE and Ansys VRXPERIENCE to design and verify the performance of intelligent headlamps in a virtual environment, automotive development teams can get advanced headlamp designs on the road quickly, confidently and affordably.

Once seen as a basic, utilitarian product feature, today automotive headlamps are becoming much more innovative - and a critical source of competitive differentiation. Intelligent headlamps, which autonomously produce adaptive light beams, are capturing the imagination of the world's automakers and consumers alike. But how can automotive engineering teams verify the performance of their complex headlamp designs, which incorporate optics, sensors and embedded software controls, under every possible driving condition? The answer lies in engineering simulation. Today, Ansys offers a complete modeling and simulation package for intelligent headlamps, including Ansys SPEOS for optics development, Ansys SCADE for software design and Ansys VRXPERIENCE for virtual nighttime road testing. By applying these industry-leading solutions in a seamless, closed-loop development process, headlamp designers can not only support extreme product innovation, but also eliminate the cost and time investments associated with manual analysis and cross-functional hand-offs. The Ansys intelligent headlamp toolkit brings together diverse development teams on a shared technology platform, delivering the high degree of speed and innovation required in a challenging automotive marketplace.

Getting Smarter About Intelligent Headlamps

Recently, the concept of smart, autonomous headlamps has been gaining traction with both automakers and consumers - and with good reason.

Nighttime driving has always been challenging, as the need to provide optimal illumination for the primary vehicle must be balanced with the danger of producing headlamp glare for oncoming traffic. Automakers have addressed this challenge through the use of high beam/low beam functionality for decades. But, as cars become more intelligent and more autonomous, headlamp design is also becoming more sophisticated.

Intelligent headlamps are creating excitement in the global automotive industry, based on their ability to detect objects in the road ahead and automatically optimize lighting conditions.

New optics technologies, such as pixel light beams, are helping to create dynamic, adaptive lighting capabilities that significantly improve driver visibility, and safety, at night. These adaptive capabilities help reveal critical objects such as lane markings, pedestrians and oncoming cars while avoiding the use of full high beams that might temporarily blind an oncoming driver.

The role of headlamps becomes even more critical when they are mounted on a car with advanced autonomous functionality. In this case, the headlamps are not just helping the driver to see better at night or in visually obscure conditions. They are also helping AD camera sensor to "see" and perform more effectively, triggering essential responses such as adjusting to the speed limit, emergency breaking and steering when a dangerous condition is identified.

Adaptive Beams: Illuminating the Engineering Challenge

It is easy to see why intelligent headlamp development has become a priority for the global automotive industry.

What is not so easy? Engineering an intelligent headlamp that will perform reliably and accurately under the nearly limitless range of nighttime driving conditions a car will encounter in the real world.

Intelligent headlamps rely on adaptive driving beam technology, which uses data from cameras and sensors mounted on the car to dynamically - and autonomously - shape the light beams that are projected onto the road ahead. This can mean:

- **Switching from low-beam to high-beam functionality** as needed to optimally illuminate the road ahead, while also guarding against glare for oncoming cars
- **Bending light around corners** to help illuminate curves as the steering wheel is turned
- **Implementing a matrix-beam strategy** in which high beams are continuously turned on, but certain LEDs in the lighting matrix are turned off when a car approaches
- **Increasing the resolution of matrix beams** to a point where navigation information or pedestrian crosswalks can be projected onto the road ahead

Light-bending capabilities help both human drivers and AD sensors to "see" around curves as the steering wheel is turned.

These complex AD capabilities rely on a combination of perception systems that gather data, underlying software controls that trigger an appropriate response, and advanced headlamp optics that carry out the command.

Because headlamps operate in a safety-critical environment, any mistake in the closed-loop sensing-controlling-lighting process can have disastrous consequences. Before being launched commercially, any intelligent headlamp product system must be exhaustively tested and proven to respond accurately to every possible real-world situation it will encounter.

However, in the race to commercialize AD technologies, it is simply not feasible to create multiple sensor-software-optics prototypes and install them on multiple vehicles and then physically test them on different roads, at different hours of the day and under every possible weather condition. Even if this were physically possible, it would mean an investment of millions of dollars and thousands of road miles.

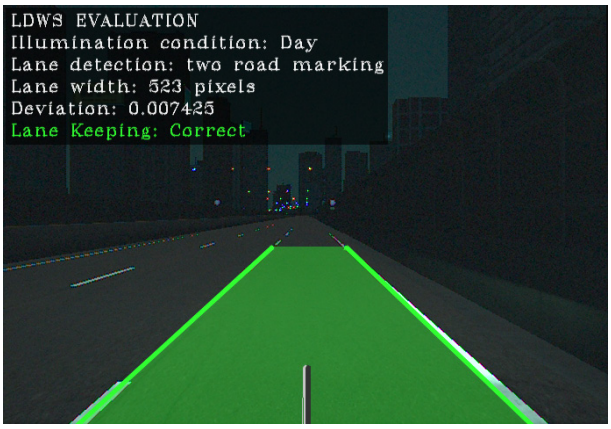
Driving Toward Product Verification, Quickly and Affordably

With so many complex technologies involved, and so many operating parameters to consider, engineering simulation is the only practical solution. By designing intelligent headlamp systems, including their embedded software controls and then validating them in a virtual testing environment, product development teams can launch new headlamp designs quickly and affordably, without sacrificing the analytic rigor necessary to ensure safety.

Ansys offers three industry-leading solutions that help cross-functional headlamp engineering teams develop and test their designs:

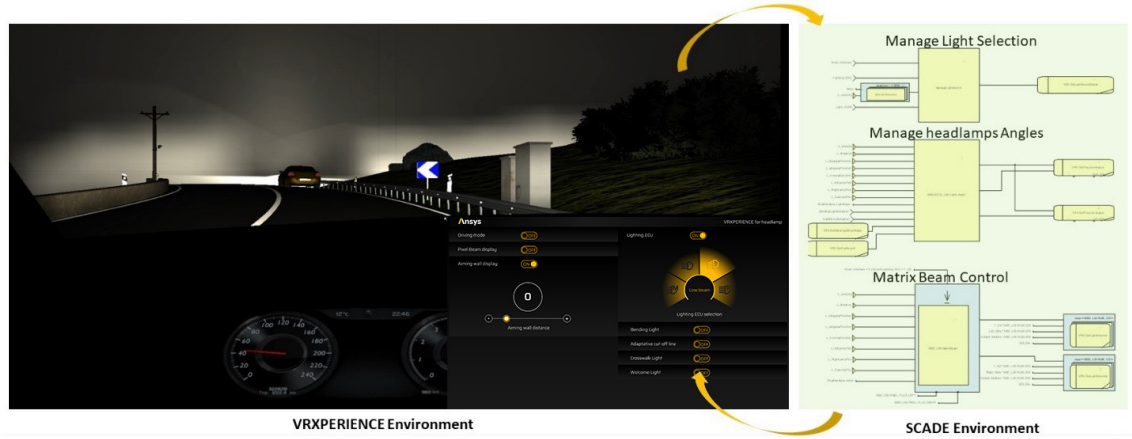
- **Ansys SPEOS** helps optical engineers design the headlamp system, including complexities such as a matrix of LEDs, in a virtual design space.
- **Ansys VRXPERIENCE** enables optical engineers to "test drive" the headlamp design, combined with its control software, in a virtual environment that replicates the physical world, thanks to optical properties and real-time, physics-based optical simulation.
- **Ansys SCADE** helps software engineers design the embedded controls that trigger an appropriate response from the headlamp system based on sensor inputs gathered from the simulated or physical environment.

By leveraging the Ansys development platform for intelligent headlamps, cross-functional engineering teams can collaborate much more effectively, handing off design tasks rapidly and iteratively. Feedback from the virtual driving tests in Ansys VRXPERIENCE can easily be looped back into Ansys SPEOS, to perfect the headlamp's design and functionality long before a physical prototype is constructed. Similarly, a virtual sensor within VRXPERIENCE is directly connected to Ansys SCADE to flag any embedded software bugs and trigger a recalculation of the control algorithms.



Ansys VRXPERIENCE includes a raw camera sensor model that validates the headlamp system's detection and decision algorithm at the model (MIL), software (SIL) or hardware (HIL) level.

This innovative, dynamic driving simulator from Ansys significantly reduces the need for road testing, light tunnels and test tracks, fueling a much faster, more cost-effective product launch cycle. It models the complete headlamp system in a comprehensive physical driving environment, ensuring that optics and embedded software with their detection and decision algorithms are engineered to deliver the best possible response in even the most unexpected situations - with little to no human intervention.



Example of a SCADE and VRXPERIENCE simulation loop for intelligent headlight control

In addition, VRXPERIENCE's direct linkage to SCADE for embedded software validation is a critical advantage of the Ansys simulation portfolio. Instead of relying on manual code definition and analysis, headlamp development teams can now leverage SCADE, a proven solution that ensures compliance with ISO 26262, the functional safety standard for AD systems. Not only does SCADE significantly reduce software testing activity, thanks to its certified code generator, but its model-based approach delivers a software design that meets functional safety needs from the earliest stage.

/ Matrix Beams: Managing the Complexity via Simulation

One example of the Ansys simulation portfolio at work is the development of complex matrix beam headlamp systems, which are growing in popularity across Europe and the United States, because of their precise nighttime lighting capabilities.

In this demo created by Ansys, a smart headlamp design can be dynamically tested to avoid glare as other cars approach.

Matrix beam headlamps allow cars to drive with their high beams permanently on. These smart headlamp systems have the unique ability to sense other vehicles on the road ahead and actually split the car's light path in response. By continuing to cast full light in the areas where there is not another vehicle, matrix beam headlamps provide complete illumination while avoiding glare in the eyes of oncoming drivers. This is possible because the light path is created using numerous LEDs that are spread over a matrix, which can then be individually controlled depending on the situation.

Because each of these LEDs can be turned on and off dynamically, matrix beam headlamps represent an especially sophisticated engineering challenge. There are numerous combinations of optics activation, which can send directed beams of light ahead of the car, and these combinations can change dynamically, in real time, as roadway conditions change. However, the LED array must be designed carefully, sensors must capture and transmit highly accurate real-time data, and embedded software controls must perform the perfect calculations needed to trigger a new beam configuration at any second.

Using traditional design tools and processes, engineering this type of advanced, autonomous lighting capability would require months or even years of manual hand-offs among functional product development teams based on trial and error. Lighting arrays and embedded software controls would be designed and "thrown over the wall" for exhaustive physical testing. Iterative redesign would proceed at a snail's pace, consuming scarce time, money and other resources. A single surprise in physical road testing might send both the optical and software engineering teams back to the drawing board.

By instead relying on the Ansys headlamp simulation toolkit, these functional teams can work seamlessly and collaboratively on the same project for extremely rapid design iteration. SPEOS, SCADE and VRXPERIENCE can be used in a closed-loop process to quickly identify any design and software shortcomings via virtual road tests, address these issues and re-test. New matrix arrays and other innovations can be explored, and physical testing conditions can be shifted, in an accelerated process that consumes just days or weeks, not months or years.

Headlamp engineering teams can be confident that their designs will work as expected in the real world, because any performance issues have been flagged at an early stage, eliminating costly late-stage rework and recoding. OEMs and consumers can be assured that their headlamps have been subjected to exhaustive testing and verification activities that meet strict industry standards.

/ Lighting the Way for Headlamp Innovation

Today, innovation has become the key word for the world's automotive engineering teams. In a race to differentiate themselves in an increasingly crowded field, automakers want to feature the newest and most advanced AD technologies. Intelligent headlamps, and more specifically digital headlights, are emerging as an important competitive edge. But, like all AD features, they must combine extreme innovation with extreme safety.

For over 50 years, Ansys has proven its ability to help product development teams push the design envelope, while still maintaining the level of analytic rigor needed to ensure safe, reliable performance. Today, a trio of Ansys products is enabling the world's automotive teams to make rapid progress in introducing new headlamp designs that will change the nature of automotive lighting.

By capitalizing on the tight integration of Ansys SPEOS, Ansys SCADE and Ansys VRXPERIENCE, headlamp engineering teams can cut significant time, costs and manual labor from the end-to-end development cycle, while also delivering the high degree of optics innovation needed to gain the spotlight today.

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